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Selection of Air Traffic Controllers for Automated Systems: Applications from Current Research

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16. Abstract

Over the next two decades, the Federal Aviation Administration's (FAA) plan for new automated systems will change the air traffic control specialist's (ATCS) job as many of the current controller's tasks become automated. The purpose of this paper was to review the findings from current research on selection of ATCS's that may guide the design of selection systems for future controllers. To accomplish this two lines of research were presented: 1) projected changes in job tasks resulting from planned automation, and 2) the current ATCS selection system. A study completed in 1987 estimated that 48 of 337 job tasks of the enroute controller would be substantially changed with implementation of the Initial Sector Suites (ISSS). In light of the projected changes, the current selection system was evaluated in terms of the methodologies used for selection and the utility and validity of those methodologies. The current job is a highly complex set of tasks and demands high levels and active application of certain cognitive abilities, such as spatial perception, information processing, reasoning and decision making. Evaluation of the changes projected in the job over the next two decades suggested that a similar performance-based selection system could maintain utility through implementation of the ISSS. However, implementation of the more advanced automation may significantly change the cognitive skills and abilities required for successful performance. Thus, work toward selection for the advanced automated environment should begin immediately.

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GLOSSARY OF ABBREVIATIONS

AAS -	Advanced Automation System
ACF -	Area Control Facility
AERA -	Automated En Route Air Traffic Control
ARTCC -	Air Route Traffic Control Center
ATACT -	Air Traffic AERA Concepts Team
ATCS -	Air Traffic Control Specialist
CAA -	Civil Aeronautics Administration
CAMI -	Civil Aeromedical Institute
CSC -	Civil Service Commission
CST -	Controller Skills Test
CTA -	Computer Technology Associates, Inc.
FAA -	Federal Aviation Administration
FPL -	Full Performance Level
GPS -	Global Positioning System
ISSS -	Initial Sector Suite System
JTA -	Job Task Analysis
KSA -	Knowledge, Skills, and Abilities
MCAT -	Multiplex Controller Aptitude Test
NAS -	National Airspace System
NOTAM -	Notices to Airmen
OKT -	Occupational Knowledge Test
OJT -	On The Job Training
OPM -	Office of Personnel Management
PVD -	Plan View Display
SME -	Subject Matter Experts
VFR -	Visual Flight Rules

SELECTION OF AIR TRAFFIC CONTROLLERS FOR AUTOMATED SYSTEMS: APPLICATIONS FROM TODAY'S RESEARCH

INTRODUCTION

Over the next two decades, the Federal Aviation Administration's (FAA) National Airspace System (NAS) Plan for new automated air traffic control systems will radically change the job of Air Traffic Control Specialist (ATCS). While the introduction of automation is not new to the occupation, the NAS Plan calls for automating more critical job tasks than could have been previously supported by technology. The challenge of selecting the controller* to operate these future automated systems is currently facing the FAA.

The first step in designing a selection system for current or future jobs is an analysis of the tasks required to perform the job. In approaching such analysis, a would-be designer of a selection system unfamiliar with air traffic control faces a challenge. Hopkin (1) has captured first impressions of the job in the following comments:

> "To a naive observer, the workspace of controllers seems complex and well nigh meaningless. It is not intuitively and immediately obvious what any of the data mean, what the tasks are, how they are done, or what would constitute successful performance."

Thus, the first step toward a successful selection system involves analysis of tasks not immediately obvious and perhaps not easily measured.

By definition, a controller is tasked with promoting the safe, orderly and expeditious flow of air traffic. This is accomplished through accurate, effective application of rules and procedures in a real-time, dynamic environment. The current ATCS's job consists of a complex set of tasks that demand a high degree of skill and active application of certain cognitive abilities, such as spatial perception, information processing, reasoning, and decision making. As an increasing number of ATC tasks become automated, the controller's participation may gradually evolve from an active manager to a more passive system monitor.

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*The terms ATCS and controller are used interchangeably throughout this paper. ATCS is the formal job title, whereas "controller" is the more familiar, informal title.

The current work force has been rigorously selected through a two stage selection system. The first stage consists of a paper-and-pencil aptitude test battery. The second stage is a performance-based measure consisting of a condensed training-testing ATC task sample in a nonradar environment. As the job itself changes, questions arise as to how long a selection system based upon the current selection criteria will be effective, and what factors will be important in designing the replacement.

To address these questions, the job of the ATCS in its current form will be reviewed and contrasted to projected changes in job tasks which will result from implementation of certain components of the NAS Plan; specifically the Initial Sector Suite System (ISSS) and the Automated En Route Air Traffic Control (AERA) software enhancements of the Advanced Automation System (AAS). The current selection system will then be examined to determine the extent to which the current selection criteria might predict success in future ATC jobs as automation causes the tasks to evolve.

AUTOMATION AND AIR TRAFFIC CONTROL SERVICES

Over the 50-year history of the ATC system's evolution, a mixture of equipment of varying technological generations and types was used. Computer automation techniques were first applied to flight data processing systems utilizing UNIVAC and IBM computers during the early 1960s. The systems were installed in six northeastern Air Route Traffic Control Centers (ARTCCs). Through this effort the FAA demonstrated that computers could be used to improve aviation safety and increase the controller's productivity. In 1968 an integrated plan to automate ATC functions was approved. This plan was NAS Stage A. By 1981 the NAS Plan for Facilities, Equipment and Associated Development was issued to define an orderly rational evolution of the system as a whole. The plan has been updated annually. The most recent version is the *NAS Plan: Facilities, Equipment and Associated Development, and other Capital Needs,* which was issued in September 1989 (2).

The NAS Plan established three principal objectives for the en route and terminal ATC systems. The first was consolidation of more than 200 facilities existing today into less than 30 by the year 2000. The second objective was to install common modular computers, software, and controller work stations (i.e., "Sector Suites"). To meet these two objectives, the en route and terminal radar approach control facilities will be consolidated into area control facilities (ACF's) with essentially identical equipment, including the HOST computer and the Initial Sector Suite System (ISSS). The third objective was the improvement of safety, fuel efficiency and productivity through higher levels of automation. The NAS Plan includes improvements such as Mode S data link, ASR-9 and advanced Doppler weather radar, navigation by Global Positioning System (GPS) satellites, and advanced stages of automation software,

such as Automated En Route Air Traffic Control (AERA). Other advances in the air traffic system that will affect the controllers' functions include point-to-point navigation and direct routing from point of departure to destination.

The NAS Plan provides for a staged delivery of the various equipment and software developments. The HOST computers have been installed and facilities await delivery of the first Sector Suites beginning in the mid-1990s.

NAS PLAN AND THE AIR TRAFFIC CONTROL SPECIALIST

Two automation advancements in the NAS Plan will particularly affect the environment and job tasks of the en route controller: Sector Suites and the implementation of AERA.

The Sector Suites provide an entirely new controller workstation. Briefly described, each Sector Suite is a collection of one to four common consoles, each of which contain data entry and display equipment. The Sector Suite consoles will provide information to the controller on multiple display screens. A common console will consist of a main and an auxiliary display, voice switching, and control panels. Display screens will have multi-color capability. Data entry devices will include a keyboard and trackball. Information presented will include a situation display of the air traffic and weather, alphanumeric flight and weather data, as well as other pertinent information, such as Notices to Airmen (NOTAM's). The most substantial change to the controller's environment presented by the Sector Suites is the replacement of paper flight progress strips with an electronic display of flight data (3).

AERA will also substantially affect the en route controller's job tasks by developing a software system, which will enhance the earlier ATC hardware and software system. AERA will support the ATCS by predicting and resolving prcblems along an aircraft's route of flight, and by planning and maintaining traffic flow and aircraft separation.

The NAS Plan proposes three stages of AERA software enhancements: AERA 1, AERA 2, and AERA 3. Under AERA 1, the computer software will detect certain common problems, such as conflicts between aircraft, violations of protected airspace, and non-adherence to ATC-imposed traffic flow restrictions. AERA 2 will then provide enhanced assistance to controllers through proposed resolution of detected problems. Several resolutions for a problem will be generated. The highest ranked resolution will be presented to the controller currently controlling the aircraft affected by the resolution. The controller will assess that resolution, examine others if necessary, and determine which resolution to choose, depending on his or her requirements for the airspace. This activity will be complicated by the increased use of direct routings instead of currently established jetways. For aircraft equipped with data link, clearances will be transmitted by the computer, once approved by the

controller. Clearances for aircraft without data link will be delivered by the controller through a voice channel. Certain coordination functions between controllers will also be automated. The controller remains responsible for all control actions with AERA 2. However, with AERA 3, automated decision-making and control will be introduced with a certain degree of autonomy for the computer to detect and resolve ATC problems without human intervention.

The NAS Plan establishes a clear path toward increased automation of air traffic control. If the current responsibility of the controller is to ensure the separation of aircraft as well as the safe, expeditious flow of traffic, then by the time AERA 3 is implemented, much of that function could shift to the computer. To design a selection system for the evolving job of the controller or to assess aspects of the current selection system that might have utility for the future, it is important to understand the job tasks of the controller and the changes that will be made in those tasks with increased automation. The following section examines the current functions of an ATCS and reviews studies analyzing the impact of Initial Sector Suite System and Automated En Route Air Traffic Control on those functions.

ATC JOB TASK ANALYSES

A job task analysis (JTA) provides a detailed itemization of the tasks required by a specific job. Such a detailed analysis can help us systematically map changes in job functions with each phase of the NAS Plan. From there we can begin to assess the knowledge, skills, and abilities required of the human operator. In addition, the JTA can help us understand what we are accomplishing with current selection systems.

In preparation for the transition to the Advanced Automation System (AAS) under the NAS Plan, Computer Technology Associates, Inc. (CTA) was commissioned to conduct a job task analysis in today's ATC environment, as well as for the planned automation capabilities. The result of this effort was a multi-volume documentation of Operations Concepts for ATC personnel in operational environments at different stages of AAS evolution. The focus was placed on the interaction between the controller and the automated system during operational tasks as described in Volume I (4).

Data were collected through field observations, interviews conducted in a large cross-section of ATC facilities and through regular involvement of a controller validation team. Thus, the JTA was completed and validated with substantial input from subject matter experts (i.e., ATCSs).

The CTA methodology derived a task list utilizing a stimulus-process-response model in which a controller performs actions in response to air traffic events. Therefore, the job analysis began with identifying and defining the air traffic events to which a controller responds. After identifying the response, the controller's action was then

decomposed to the task level--the central analysis result. Within this framework, the work performance actions were classified into three increasingly detailed levels: activities, sub-activities, and tasks. Activities were the highest level of description of operational job functions. The operational duties of a position were typically described with five to nine activities. Sub-activities were a more detailed statement of the work performed, and a task was the most detailed unit of description.

Within the task level specification, four task types were identified as follows: 1) ENTRY tasks (i.e, entry of data into the system), 2) RECEIPT tasks (e.g. receipt of information from the displays), 3) ANALYTICAL tasks, and 4) VERBAL COORDINATION tasks (coordination with other individuals or the system).

Task characterization analyses were also performed that described tasks on four separate dimensions. Two of these dimensions are of particular interest in establishing a controller selection system. These two task characterizations are 1) the cognitive/sensory attributes required for a task and 2) the identification of task performance requirements.

For purposes of this paper, only the tasks required of the controllers working in Air Route Traffic Control Centers (ARTCCs)--the en route controllers--will be reviewed. These are described in Volume VI of the Operations Concepts documentation (5). Six activities were identified for the en route controller in the current ATC environment, as follows:

1) perform situation monitoring;
2) resolve aircraft conflicts;
3) manage air traffic sequences;
4) route or plan flights;
5) assess weather impact;
6) manage sector/position resources.

Within the 6 activities, 46 sub-activities and a total of 348 distinct tasks were identified. Clearance delivery was identified as a set of tasks that was relevant to many sub-activities and was thus defined as a "macro" performed as a function of a number of tasks.

The cognitive/sensory attributes required for performing tasks of extreme or high criticality were identified. Fourteen attributes were found to be relevant to performance of computer and radar workstation jobs associated with current ATC: coding, movement detection, spatial scanning, filtering, image/pattern recognition, decoding, visualization, short-term memory, long-term memory, deductive reasoning, inductive reasoning, mathematical/probabilistic reasoning, prioritizing, and verbal filtering. (Definitions for these attributes are included in Appendix A).

Further Analysis of each of 161 critical tasks revealed that analytical attributes such as visualization (42 tasks), short-term memory (30 tasks), deductive reasoning (41

tasks), and mathematical/probabilistic reasoning (32 tasks), were key cognitive attributes. Additionally, message filtering (40 tasks) and decoding (57 tasks) were important.

AFFECT OF ISSS AND AERA ON JOB TASKS

The Initial Sector Suite System

In 1988, Computer Technology Associates completed a report of the impact of the Initial Sector Suite System on ATC procedures and training (6). Expanding on a prior report, the analysis provided an early identification of current ATC procedures projected to be affected by ISSS. The analysis for the report compared the Operations Concepts for the current job, described above, and the Operations Concepts prepared for ISSS utilizing the same job analysis methodologies (7). The study estimated that 48 of 373 (13%) job tasks of the en route controller would be substantially changed from the current ATC system; 237 (64%) would be essentially unchanged. The remaining 88 tasks would be affected to some degree, but not substantially changed.

CTA observes that the ISSS introduces substantial changes to the en route controller's operations. In general, the ISSS will provide the controller with greater flexibility and capability in data handling. There will be increased data processing and flight data will be available more rapidly. Entry of data into the system will be increased over today's requirements.

While a comparison of information displayed reveals a distinct parallelism between current sector workstation physical displays and written records and the Sector Suite workstation, the manner in which controllers manipulate the data will be significantly changed. The most substantial change with ISSS is the conversion of paper flight progress strips to electronic flight data entry and electronic display and manipulation of the data. Today's flight progress strips are manually inserted into plastic holders, placed in sequence in a strip bay, marked with a pen, sorted, flagged, and removed. Under ISSS all of these actions will be accomplished electronically. Computer Technology Associates notes that display management will be much more critical with ISSS than with today's system, because more information will be available under ISSS and will need to be displayed for most efficient use. CTA also expresses a concern that electronic presentation of data may impact the silent coordination between the radar and radar associate ("D-side") controllers.

In summary, the 48 radically and significantly different tasks under ISSS pertain to the controllers' interaction with information displays and the input of control data and messages. CTA's analysis of changes in the cognitive/sensory attributes of these tasks determined that "coding" will be substantially increased because of the expanded availability of messages. CTA concluded that cognitive and sensory

attributes required for the more critical controller tasks in both the current ATC system and under ISSS would be similar. In terms of performance requirements, the accuracy of data entry would become critical and the frequency of receipt of information from the system would increase.

Automated En Route Air Traffic Control (AERA)

Researchers at MITRE, in conjunction with teams of controllers as subject matter experts, prepared several papers assessing the changes in the en route controllers' operational functions after implementation of AERA. AERA 1 introduces primarily problem detection capability and some decision aids for the en route controller. However, AERA 2 expands these capabilities in several important areas. These areas include resolutions to problems detected by the automated problem detection software, display of proposed resolutions to the appropriate controller, and finally provision of additional aids to assist a controller in decision-making for separation of air traffic and coordination.

Carlson and Rhodes (8) described the changes in the controllers' work activities in AERA 2. In today's environment, controllers rely on their own mental abilities to detect and resolve problems occurring in their airspace. ATCSs must recognize potential loss of separation between aircraft based upon available data in flight progress strips and plan view displays (situation displays) showing computer processed radar returns of current and recent past aircraft positions, and their knowledge about the operational ATC environment. Upon recognizing a potential problem, the ATCS must formulate and evaluate resolutions for the situation. The human being has a finite capacity to process information. Limits include the maximum number of aircraft an invididual can safely and efficiently control at any one time, as well as the look-ahead time to project potential conflicts. Introduction of direct routing of aircraft and reduced use of established airways may, in fact, overload a controller's information processing capabilities.

AERA 2 should expand the capacity of the ATC system by automating the detection of problems up to 20 minutes prior to predicted loss of separation and for an aircraft's entire route of flight. The Automated Problem Resolution (APR) function will produce a number of resolutions based upon the aircraft's projected trajectory, geometry of the conflict, airspace characteristics, and other aircraft or system requirements. This capability is projected to improve detection and resolution of problems because they will be detected earlier, allowing more optimal resolutions to be considered.

The affect of AERA 2 on the controller's job has been described by Carlson and Rhodes (8) as shifting the emphasis away from tactical decision-making to more strategic management of the ATC environment. They suggest that many routine tasks will be automated, and more complex tasks will become easier because of the availability of computer proposed resolutions, suggesting that controllers will rely less on their own mental abilities to monitor flight data and identify situations requiring

control actions. The focus of the controller's attention will shift from the flight data and situation display to the problem alert and resolution displays. Finally, they suggest that because problems will be resolved earlier than they are in today's system, the controller's time orientation for detecting and resolving ATC problems will change.

Another perspective on the time orientation of the controller under AERA was provided by McKinley and Jago (9). In an early evaluation of the en route controller's skills requirements, they suggested that the automated control capability of AERA would only be possible for long-term (greater than 20 minutes in the future) and some medium-term (6-20 minutes) problem prediction and resolution. For the short-term (0-5 minutes) and some medium-term problem detection, reliance on the information from the situation display and electronic flight progress data would continue to be required.

Because AERA 2 and AERA 3 are still under development, it is difficult to assess the cognitive skills and abilities required for the job tasks. However, it is clear that the implementation of AERA 2, and particularly AERA 3, will significantly affect the role of the ATCS in controlling traffic and that research on the impact must continue.

CURRENT SELECTION OF AIR TRAFFIC CONTROL SPECIALISTS

PERSONNEL SELECTION IN THE UNITED STATES

The discussion of selection of controllers should be considered within the context of selection of personnel, in general, in the United States. That context is highly regulated, considerably politicized, and normally very public. Prior to the Civil Rights Act of 1964, selection was a backwater of personnel psychology, including only a few individuals of talent and sensitivity among its ranks. Civil rights activists perceived, mostly accurately perhaps, that the selection procedures followed by many companies bore little relationship to the jobs at hand while they excluded high percentages of minority applicants. Much of the early case law on personnel selection was built from such cases. It could be argued that many of the resulting judicial opinions overgeneralized and, by inference, developed procedural requirements that few, if any, of the best selection systems could meet. Since the 1960s, selection procedures have become the subject of scrutiny by many different groups. This has meant that the procedures must be both extensively documented and technically acceptable. Because of this, personnel psychology left its position in the backwaters and has become one of the more exciting areas of scientific psychology.

The Uniform Guidelines on Employee Selection Procedures, published in 1978 (10), apply to public, as well as private employers. They include two major requirements: the determination of adverse impact and the demonstration of job-relatedness. If an employer's selection system shows adverse impact against one or more selected groups, then the job-relatedness of this system must be demonstrated. The debates surrounding the proposed Civil Rights Act of 1990 have focused on defining these terms "adverse impact" and "job-relatedness." For now, however, "adverse impact" can be understood as the amount or degree of differential effect that a selection procedure has against a protected group, that puts the employer on the defensive and initiates an investigation of the selection procedure. This is primarily a legal or administrative matter, although psychologists are concerned about representativeness of samples, statistical significance, and so forth.

Job-relatedness is the concern of psychologists. Over the past 25 years it has been understood as meaning the demonstration of the validity of the selection procedures, with criterion-related validity providing the most persuasive evidence. Showing a significant statistical relationship between the scores on a predictor test and the scores on some criterion, typically training grades or supervisory ratings of job performance, has been convincing in many cases. Content validity can be acceptable in certain circumstances, such as using a typing test to select for clerical occupations. The FAA's Screen for ATCS, described below, is based on both a content validity strategy--the Screen is a miniature training and test situation of how a controller learns the job--and a criterion-related strategy--Screen grades predict field training performance. A third strategy is construct validity where some cognitive ability (e.g., the construct of spatial orientation of objects) is posited as necessary to the ATCS occupation. Construct validation strategies can be risky legal defenses unless their empirical grounding is well-articulated.

A major contribution to the understanding of validation in personnel settings is the concept of validity generalization, initially proposed in 1977 by Schmidt and Hunter (11). These authors, and others following, collected many criterion-related studies and used the study results as data in meta-analyses. Validity coefficients vary widely from one study to the next, a phenomenon many scientists had interpreted as supporting "situational specificity;" that is, the use of one predictor test cannot be generalized from the situation where the criterion-related validity study was performed. Schmidt and Hunter (7) showed that this variability in validity coefficients might be due not to variability in situations, or employment settings, but to the varying numbers of subjects in the studies, the differing reliabilities of criterion measures, and other artifacts; that is, criterion-related validities do generalize to other situations.

There have been two major outcomes of the validity generalization movement--and it does have some of the characteristics of a movement. First, it has restored both the faith in and reliance on paper-and-pencil tests of general mental abilities as entry-level predictors of success in most jobs. While some argue that a test of general mental ability is useful for any occupation, the historical distinctions among test types (e.g., verbal, quantitative, spatial) reflect small but important differences in

predicting job success. Such generic paper-and-pencil tests are still a major component of personnel selection. Further distinctions among test types and the mental processes required to perform well on them, such as those being explored by cognitive psychologists, are usually of much less interest because these distinctions are not reflected in predictiveness. However, those responsible for the selection of air traffic controllers may have more interest in this cognitive approach, because of test practice effects especially prevalent in spatial ability tests. Fairness issues as well as validity are paramount in this approach.

The other outcome of validity generalization has been to focus more on the criteria that the tests have been used to predict. Most of the validity generalization research is based on only two classes of criteria: training success and supervisory ratings. By the time the validity generalization research began in the late 1970s, civil rights activists and some personnel psychologists were questioning these two criterion categories. While training is important, so went the argument, it is not the job. Training may require more cognitive processing, which paper-and-pencil tests predict fairly well, than may the job. As for supervisory ratings, these are typically generic, probably hodge-podge, and possibly biased. Why, argued these critics, can we not validate our selection procedures against closer surrogates to actual job performance?

The use of job performance measures in criterion-related validity research is fraught with conceptual and logistical problems of high order. On the conceptual side, should we deal with "typical" performance, that which the employee does on a regular basis and that might be measured by detailed supervisor ratings? Or should we try to measure "maximum" performance, what the employee can do, by developing specialized situations in which the desired performance can be evaluated? What types of performance should we measure? Should we measure performance with a test of knowledge, or a demonstration, or a simulation? How useful are archival measures, such as absenteeism? Logistically, most employees are far more scattered in time and place than are applicants for a job. Further, since job incumbents tend to specialize, how can a single, albeit complex, performance measure be fair to all?

The research on performance measurement is not as advanced as that on tests and predictors, but during the last decade there has been progress. The major effort has been a joint-military service effort sponsored by the U.S. Department of Defense. Preliminary answers to the questions raised above are (3) job performance can be measured; (2) job performance measures can be used in criterion-related validity research and can be predicted by multiple abilities test batteries; (3) the most appropriate performance measures will differ from job to job, e.g., knowledge tests would be appropriate for claims examiners but not for mechanics; (4) all available performance measures, including archival measures can be used to describe a "performance space," to provide a more complete picture of the occupation and its requirements.

An emphasis on performance assessment, or on criterion-referencing, has been growing steadily during the last two decades in many areas of psychological research. The most prominent example is that of educational assessment. It no longer is sufficient to have a comparison to "who," the traditional basis of norms-referencing; it must be a comparison to "what," or criterion-referencing, and why that "what" is important. Competency requirements for high school graduation are an example.

Performance measures may also be used in ways not previously considered for training grades and ratings, and it is this potential that is most exciting. For example, let us say a work sample test were developed for a subgroup of Full Performance Level (FPL) air traffic controllers. Say that this measure could be judged as a representative sample of controller performance by an appropriate sample of controllers and their supervisors, and that the test scores could be scaled into ranges such as Outstanding, Exceptional, Fully Satisfactory, Marginal, and Unacceptable. If this performance measure has a valid predictor that we would like to use in our selection procedures, we can link the score levels on the work sample to score levels on the predictor in both a more rational and more empirical manner than is the current practice.

Thus, the state of the art in selection research is: (2) It is strictly regulated, very public, heavily documented, and of mostly high quality; (2) Using paper-and-pencil tests of general abilities has much technical justification; and (3) Performance measures are becoming much more necessary in validation of selection procedures. It is likely that computers will play an increasing role in selection research and in selection, as they have in other areas of human endeavor. However, the question for the technology will be the technical adequacy of the selection research program in which it is embedded. Research in selection of air traffic controllers of the future will take place in this environment and must meet the existing standards and regulations for employee selection.

SELECTION OF AIR TRAFFIC CONTROLLERS

History of the development of ATCS selection procedures.

The FAA has chosen to utilize a selection system prior to investing in training individuals as ATCSs. The reason for the decision was a high attrition rate from the occupation when no formal selection system was utilized prior to entry into training. The attrition was generally due to training failure and occurred, on the average, two to three years into a person's career in air traffic (12). Such late attrition resulted in considerable costs to both the FAA and the ATCS, who found little opportunity to apply the ATC skills in other occupations. Toward the goal of reducing attrition as well as identifying the individual characteristics required for success in the occupation, the FAA developed an active selection research program.

As described by Brokaw (13), research on ATCS selection dates back to the 1950s and his contract with the Civil Aeronautics Administration (CAA--precursor to the FAA) for the development of a paper-and-pencil aptitude test battery that could be used to select ATCS trainees. The results of the study indicated that some aptitude tests reflecting content areas identified from a job analysis could potentially contribute to the selection process. (This study provided the format for an Air Traffic Problems test). In a joint effort with the CAA, the United States Air Force Personnel Laboratory administered 37 aptitude tests to ATCS trainees in 1956. The findings indicated that a composite aptitude test score--created by adding scores on tests of arithmetic reasoning, symbolic reasoning, code translation, and the ATP test--effectively predicted instructor's ratings of training performance and supervisors' ratings of job performance approximately one year after training.

Research continued in 1960 with the establishment of the FAA Civil Aeromedical Research Institute (presently the Civil Aeromedical Institute--CAMI), as described by Collins, Boone, and VanDeventer (14). CAMI research on Civil Service Commission (CSC) tests of similar content to the tests originally studied by Brokaw led the CSC for the first time to establish tests for selecting ATCS trainees. Test requirements for selection were implemented in 1962. The initial selection test battery consisted of the following: Arithmetic Reasoning, Spatial Relations, Following Oral Directions, Abstract Reasoning, and Air Traffic Problems. During the period between 1962 and 1972, in addition to continuing validation research, aviation psychologists studied a number of factors relevant to ATCS selection: attrition from the profession, age, prior experience, education, sex, and military ATC training.

Implementation of the CSC test battery alone failed to sufficiently decrease the attrition rate. Prior to 1976, attrition rates from field training were 38%. A number of studies were completed in the early 1970s, as well as Congressional hearings of the Committee on Government Operations, which resulted in several recommendations. As a result of the reports, the FAA developed a standardized, centralized, validated program designed to identify, as early as possible, and remove from training those candidates demonstrating insufficient aptitude to become ATCSs. The program was designed to decrease the costs of attrition and improve the selection of ATCSs. The FAA's aviation psychologists collaborated to provide a scientific framework required for the design, implementation, and evaluation of the program.

The result was the implementation of a second-stage selection procedure designed to follow the CSC test battery. This second-stage hurdle consisted of two option-specific (en route and terminal) pass/fail programs utilizing courses similar to those used in the nonradar separation portions of the FAA Academy ATC training curriculum existing at that time. Grades in these courses had been found to be predictive of future field attrition (12). The programs were implemented in 1976.

During the latter half of the 1970s a new initial selection test was developed. Research focused on studies relevant to the Uniform Guidelines on Employee Selection Procedures, and on developing field training performance ratings,

developing a longitudinal database for continuing validation research, and refining optimal combinations of old and new aptitude screening measures (14).

The current ATCS selection system.

The current ATCS selection system consists of two hurdles or stages of assessment. The following sections present these procedures in more detail and give statistics on each method's ability to predict other measures of ATCS performance.

The OPM Selection Battery. The first stage of the selection process is the Office of Personnel Management Air Traffic Control selection test battery. This stage is a paper-and-pencil format aptitude test battery consisting of three tests: the Multiplex Controller Aptitude Test (MCAT), Abstract Reasoning (included from the prior selection battery), and the Occupational Knowledge Test (OKT). It provides the usual benefits of paper-and-pencil tests, allowing initial assessment of large numbers of potential candidates at relatively low cost.

The MCAT was developed to establish a paper-and-pencil test with higher predictive validity than tests included in the CSC selection battery. The MCAT was designed to approximate simulated air traffic activities. Simulated airspaces depict several aircraft traversing the space. An altitude, speed and route chart is also presented. Candidates are asked to identify situations that may result in conflicts between aircraft based upon a limited set of separation criteria. Other items require computing time-distance functions, interpreting information, and recognizing spatial relations. The test is in a timed, multiple-choice format. The Abstract Reasoning measures two principles of logical development exhibited by sequences of figures and letters (14). The Occupational Knowledge Test (OKT) provides a more objective and reliable measure of a candidate's ATCS job knowledge than that which was provided by ratings based upon job history. Items on the OKT cover seven knowledge areas related to air traffic control.

This battery, as is true of many others, including spatial ability tests, is highly subject to practice effects. Generally, a second, higher score has lower validity than the first score. To compensate for practice effects, applicants earning a score of 70 or above (out of a possible 100) presently cannot retake the OPM Selection Battery for 18 months.

The FAA Academy Screen. The second stage of the selection process is the FAA Academy Screen, a nine-week assessment program equivalent to a miniaturized training-testing environment. Candidates are taught rules for aircraft separation and

are assessed in laboratory simulation problems on their ability to learn and apply the rules. This pass/fail stage is very resource-intensive, but selects candidates likely to succeed to full performance level from among those who have passed the initial OPM battery.

The goal of the second stage program, which was implemented in 1976, was to reduce field attrition through early identification of candidates with little chance of succeeding in field training. Because the Screen is a miniaturized training-testing assessment program, its purpose is to teach a candidate, with no knowledge of air traffic control, enough about the job to assess the potential to succeed to the full performance level. This is accomplished by training the candidate in aspects of the job and assessing performance on a sample task (i.e., separating aircraft in laboratory nonradar simulation problems). The complexities of the laboratory problems are structured to escalate quickly, generally beyond most candidates' ability to master the complexity levels being tested. This allows for a certain level of discrimination of the better candidates from the candidates with less ability.

The program includes four weeks of didactic, classroom training on nonradar ATC rules and principles. Content includes rules of separation (vertical, longitudinal, and lateral), cooperative agreements, protection of special-use airspace, phraseology, and flight progress strip-marking. Scme practice in applying the rules is provided in the classroom. For the final five weeks, training focuses on application of the rules in a nonradar laboratory. Each student performs nonradar controller job tasks in one or two thirty-minute scripted scenarios each day. During each scenario an individual instructor is assigned to each student. Following the scenario, the instructor reviews the student's performance with the student, providing feedback on errors, correct application of rules, and other required skills.

Thirteen performance measures are made of each candidate during the nine-week period. Five of these assessments are multiple-choice tests on the academic portion of the Screen. These assess the candidate's ability to learn and retain the basic knowledge required for the job. A sixth measure is a map test which assesses the students' ability to learn a map of the relatively simple synthetic airspace. These measures account for 20% of the final grade. Six of the performance measures are formal evaluations of the student's performance during six 30-minute standardized scenarios. The score on these laboratory simulation problems consists of a technical assessment (number of errors) and an instructor assessment (subjective evaluation of student performance). Only five of the six laboratory problems are included in calculating the final score. These five scores, however, comprise 60% of the final grade. Finally, the students are given a timed, multiple-choice test, the controller skills test (CST), which is a paper-and-pencil assessment of the students' ability to apply ATC rules and procedures. The CST comprises 20% of the final composite grade. A final grade of at least 70 (out of a possible score of 100) is required to pass the Screen. Failure to achieve a composite score of 70 results in removal from the ATCS job.

The ATCS selection procedures and field training status and attrition rates.

As noted, the Academy screening programs were implemented in 1976 to provide early identification and removal of candidates with little chance of success in the occupation and thus reduce field attrition rates. Prior to 1976, the attrition rate in field training was 38%. After implementation of the screening programs, attrition rates at the Academy averaged 30% and field training attrition declined to 8% (15). Following the 1981 controllers' strike and subsequent increase in the population of Academy entrants with no prior ATC experience, the attrition rate at the Academy increased to 40%, while the field attrition rate increased to 11%. Thus, the Academy screening programs were effective in decreasing attrition from field training.

To determine the extent to which the original OPM and Screen measures predicted subsequent measures of performance in field training in the en route (ARTCC) environment, Manning, et al, (16) compared correlations between the OPM ATCS selection test scores and scores from the FAA Academy Screen with measures of field training performance for competitive Academy students who entered between September 1981 and September 1985. Of the OPM measures, the MCAT was found to be a better predictor of field training status in the en route option than other OPM tests. Academy laboratory performance scores were found to be more predictive of field training performance than the academic test scores. Finally, for the en route option, Academy performance measures, particularly laboratory scores, were better predictors of supervisor and on-the-job training (OJT) instructor ratings and training status than were OPM scores.

Current correlations between performance on the OPM battery, Academy Screen, and field training status.

In October 1985, a change was made to the Academy Screen which resulted in reweighting the performance measures. Because the average time for an en route ATCS to attain full performance level (FPL) status is just under 3 years, we are just now able to evaluate the impact of this change on predictive validity. The analyses reported here are an initial evaluation of the change. Because this paper has primarily focused on how increasing automation affects the en route controller, the analyses address only the en route option. In addition, a modification to the OPM test battery administration procedures was also implemented in October 1985. Because the affect of the change has not yet been evaluated, this paper presents only data from ATCSs who took the version of the OPM test prior to the modification.

To assess the validity of the new Academy Screen, analyses were conducted to examine the distributions of OPM and Academy scores for first-time competitive

students who entered the Academy between October 1985 and September 1986, (i.e., during FY-1986). As noted, the sample included only students with OPM ratings from the former administration procedures and only those students assigned to en route facilities. Finally, ATCS developmentals were excluded from the sample if they withdrew from the career field for reasons other than failing training (e.g., to pursue another career).

Appendices B-E show statistics related to the distributions of OPM test scores and Academy performance measures. Means and standard deviations of OPM test scores for all applicants who took the OPM test between April and October 1985 are shown in Appendix B. Means and standard deviations of OPM test scores for those who entered the Academy between October 1985 and September 1986 and took the prior administration of the OPM test are shown in Appendix C. Means and standard deviations for Academy performance measures are shown in Appendix D. Appendix E shows correlations between OPM test scores and Academy performance measures.

Tables 1 and 2 show correlations of OPM and Academy performance measures with a variable measuring status in field training, both unadjusted and adjusted for restriction in the range of predictor scores, respectively. The variable "field training status" has the following categories: 1) reached FPL, 2) still in training, 3) switched options, and 4) failed. The tables compare the correlations reported in the Manning, et al, (16) study with those computed for the FY-1986 sample of Academy Screen graduates assigned to the en route option. It can be seen that the correlations are similar. Examination of Table 2 shows that the correlation between the OPM rating and field training status, corrected for restriction in the range of OPM rating, is higher than was found for the 1981-1985 sample, although the correlations of individual OPM component scores with the criterion were similar.

TABLE 1
CORRELATIONS BETWEEN OPM AND ACADEMY SCREEN PERFORMANCE MEASURES
AND MEASURES OF FIELD TRAINING STATUS
For 1981-1985 En Route and 1986 Screen Entrants
(Uncorrected for restriction in range)

	1981-1985 En Route (n=2992)	1986 Screen (n=402)
OPM TEST MEASURES		
Multiplex Controller Aptitude Test (MCAT)	-.12*	-.09
Abstract Reasoning	.03	-.03
Occupational Knowledge Test (OKT)	.00	-.05
Transmuted Composite (TMC)	-.10*	-.08
OPM Rating	-.05*	-.09
ACADEMY SCREEN MEASURES		
Block Test Average	-.05*	-.06
Controller Course Test	-.04	-.07
Ave. 5 of 6 Laboratory Problems	-.24*	-.21*
Ave. Instructor Assessment	-.25*	-.22*
Ave. Technical Assessment	-.22*	-.21*
Controller Skills Test	-.08*	-.16*
Comprehensive Score	-.24*	-.24*

*Correlations were significantly different from 0 at p<.01.

TABLE 2
CORRELATIONS BETWEEN OPM AND SCREEN PERFORMANCE MEASURES AND MEASURES OF FIELD TRAINING STATUS
For 1981-1985 En Route and 1986 Screen Graduates
(Adjusted for restriction in the range of predictor scores)

	1981-1985 En Route (n=2992)	1986 Screen (n=402)
OPM TEST MEASURES		
Multiplex Controller Aptitude Test	-.28	-.24
Abstract Reasoning	.05	-.04
Occupational Knowledge Test	.00	-.04
Transmuted Composite	-.25	-.24
OPM Rating	-.13	-.30
ACADEMY SCREEN MEASURES		
Block Test Average	-.09	-.10
Controller Course Test	-.05	-.09
Ave. 5 of 6 Laboratory Problems	-.42	-.36
Ave. Instructor Assessment	-.46	-.37
Ave. Technical Assessment	-.33	-.30
Controller Skills Test	-.14	-.26
Comprehensive Score	-.46	-.44

Also, the correlations of the Laboratory Average (average score on best 5 of 6 laboratory problems) and Laboratory Instructor Assessment (average score on instructor subjective rating in laboratory problems) with en route field training status decreased somewhat, while the correlation between the CST (Controller Skills Test) and en route field training status increased somewhat. For the remaining measures, the similarity in correlation coefficients for the two samples suggests that the validity of the program in predicting status in field training has remained stable, in spite of the changes made to the Academy Screen.

Use of Nonradar ATC Tasks to Predict a Radar-based Job

The Screen program is based upon nonradar air traffic separation rules. At the time it was developed, nonradar procedures were used more frequently. Today, radar separation procedures are utilized almost exclusively in the majority of the ARTCC's. Thus, the question arises about the extent to which a program that is based on nonradar procedures may effectively predict success in a radar environment.

A comparison of the ATC tasks trained in the Academy Screen to the tasks required of an en route controller suggests that many of the behaviors measured in the current Screen are similar to those required in the radar environment. Of the six activities of an en route controller identified in the CTA job task analysis (1. perform situation monitoring, 2. resolve aircraft conflicts, 3. manage air traffic sequences, 4. route or plan flights, 5. assess weather impact, and 6. manage sector/position resources), the Screen assesses tasks associated with five of the six activities. Only weather assessment (activity 5) is not taught or tested in the Screen program.

With the exception of the tasks that require checking the plan view display (PVD) or utilizing radar separation procedures, most of the tasks in the composition graph are similar to the nonradar training taught and evaluated in the Screen. For example, the first sub-activity under "perform situation monitoring" is checking and evaluating the separation of aircraft. The sequence of tasks for this sub-activity proceeds as follows: i. Review of flight progress for present and/or future aircraft separation; ii. Review of PVD (or flight progress strips in nonradar) for potential violation of airspace separation standards; iii. Review of location of flight progress strip in bay, if unsatisfactory, resequence manually; iv. Mental assessment of potential conflict--project mentally an aircraft's future position/altitude/path and evaluate mental flight plan projection for appropriateness; v. Range/bearing data may assist assessment of possible conflict--request range/bearing/time (by contacting the pilot in nonradar). Of 18 tasks described for the sub-activity, 12 tasks or nonradar correlates are assessed in the Screen. This is an example of the extent to which the tasks taught and assessed in the Screen can be related to the tasks required of an en route controller even though radar equipment has added an automated dimension and new, specific air traffic separation procedures.

Knowing that performance on nonradar tasks has some utility in predicting future success in the more highly-automated radar-based occupation may help develop selection procedures for the automated systems of the future. Perhaps selection procedures designed for the current occupation will predict performance in the evolving occupation.

Because of the ATCS strike in 1981, development of a radar-based selection program was delayed. Recently, however, interest and enthusiasm for addressing questions of new and improved selection procedures for ATCSs have been revived.

COMPUTERIZED SELECTION SYSTEMS

Since the development of the FAA's selection procedures, the use of computers in assessment has become more feasible and may have some utility for future selection of ATCSs. Much interest and effort during the last two decades have been devoted to creating computer-based assessment and selection systems. A number of computer-based assessment systems are available commercially. Some are directed towards clerical occupations while others are marketed for both vocational guidance and selection, using computer-adaptive multiple cognitive abilities batteries.

Further selection applications have been few. However, several problems complicate the application of computerized testing to the selection of employees. First, typical test construction problems of standardization also apply to computerized tests, as well as the computer-specific problems of calibration and user-friendliness. Second, when an organization has computers, it is not hard to justify the use of some of them for testing. When the selection function requires its own set of computers, it is difficult for the organization to justify the use of all of them in testing. Thus, large-scale computerized selection programs, such as might be expected in the military services, have been difficult to implement. Third, the selection research base for abilities measurable only by computer, such as dynamic spatial ability and processing speed, remains comparatively slim. The three military research laboratories in the United States have each developed computerized assessment systems, which measure abilities different from those assessed by paper-and-pencil selection tests. As this research base develops, computers are likely to play a larger role in selection.

FUTURE SELECTION SYSTEMS

This paper has presented an overview of the NAS Plan for automation of the air traffic controllers' job over the next two decades. To the extent that changes in job tasks have been projected so far, we have attempted to map them for the Initial Sector Suite System and Automated En Route Air Traffic Control. At this time, it appears that the job of the ISSS controller will require many of the same skills and cognitive attributes required today. The implementation of AERA, however, should begin to substantially change the involvement of the controller from a tactical mode of operation to a more strategic mode.

Clearly, much of the controller's activity when operating AERA 2 will involve examining data, testing resolutions, and communicating with the computer, aircraft, or other controllers. While a controller will still need to be able to visualize interrelationships between aircraft, the need to make rapid decisions using the information will be reduced. The description of controller activities provided by MITRE suggests that it might be appropriate to select controllers with different types of skills, emphasizing strategic instead of tactical planning. This would suggest that

a different battery might be appropriate for selecting AERA 2 ATCSs.

The problem with the description of the future controller being exclusively one who executes the computer's suggestions is that different skills may be required if control actions are required in a short-term time frame, perhaps a shorter time frame than the computer can resolve, or during emergencies. For example, if events (e.g., VFR popups) occur that are not identified by the computer, then the controller may be required to respond quickly to avoid loss of separation between aircraft. These actions are complicated by the proposed "direct routing" of aircraft from one destination to another, without using designated airways. If emergencies requiring controllers to engage in tactical control activities occur only rarely, and if tactical ATC is be complicated by direct routing, then perhaps the future controller will require skills at separating traffic that exceed those required today. As long as the controller retains responsibility for the movement of all aircraft in the assigned airspace (even though the computer ordinarily provides resolutions to potential conflicts), then he or she will have to possess and be able to maintain the KSAs to "manually" separate those aircraft, in case of emergency. Therefore, in this case, the selection of ATCSs must be based on the requirement to perform under the worst-case scenario. If, over time, the AERA software is accepted as accurate, and is found to be able to handle all emergency situations, then the responsibility for the aircraft may be removed from the ATCS and assigned to the computer, and the controllers' job requirements may be changed, resulting in modifications to selection procedures.

As plans for AERA 3 become more fully developed, the tradeoff of separation responsibilities between the ATCS and the computer will become more pronounced. Preliminary projections are that the AERA 3 software will undertake all control activities, perhaps leaving the ATCS to issue clearances to aircraft that do not have data link capabilities, or perform traffic management activities. The controller may also be responsible for ensuring that the computer is operating properly. In all cases, even through AERA 3, the computer is dependent on timely, accurate input of information from human operators and is, thus, vulnerable to the reliability and accuracy of the human. Again, if the controller has responsibility for taking over the control of air traffic when (if) the computer fails, then the selection procedures must identify those who have the ability to control traffic, even if they only do so on rare occasions. If, on the other hand, the full responsibility for aircraft separation lies with the computer (perhaps yet another level of software), then selection procedures can be targeted to the KSAs required to perform the duties most frequently performed by the ATCS using AERA 3.

Development of any selection procedure depends on an accurate description of the tasks to be performed and the knowledge, skills, and abilities (KSAs) required to perform those tasks. The problem with applying this approach to the development of selection procedures for the "automated controller" is obtaining a sufficiently detailed job/task analysis prior to implementation of the new system, because no controllers will have used the system extensively enough to qualify as subject matter experts (SME's). A fallback position would be to work with controller members of

the Air Traffic AERA Concepts Team (ATACT), who are as knowledgeable as any controllers about the way the new system will work. These "near" SMEs could speculate about the requirements to perform the tasks. Preliminary work can be done early in the development cycle to identify or develop tests to measure the KSAs, as they are currently identified. Review cycles will have to be built into the process to allow periodic review of the KSAs with SMEs as more controllers are brought into the loop to test the AERA software and procedures, and as the software and procedures become increasingly well-defined. Using such an iterative process, a tentative set of selection procedures would be available upon implementation of the new system.

When contemplating the development of selection procedures for employees who will be ATCSs under the AERA levels of automation, it is clear that work must begin now for the procedures to be ready when AERA 2 software is installed. At the same time, the division of duties between the software and the controller have not yet been finalized, so the final choice of a selection procedure is premature.

Because of the criticality of the ATCS occupation, it may not be possible to select everyone who applies for the job and passes the new selection procedure for a period of time until the validity of the new selection battery can be established. When converting to the AERA system, it may be necessary to also continue using the old selection procedures for awhile, until the validity of the new procedures can be evaluated. The correlations between measures of performance in the nonradar Screen and success in radar-based field training suggest that using a selection procedure current, for example, for the radar job to select controllers for the new ATC job under ISSS may be an acceptable interim solution while validation of the new procedures occurs.

Furthermore, several years may be required to establish the validity of new selection procedures. Most of that time is needed for those selected to complete field training so that on-the-job performance can be measured, and the relationships between selection predictors and job performance criteria can be assessed. Measures of performance in training can be used as interim criteria, but, as previously mentioned, are less desirable than measures of job performance.

DISCUSSION

The research from the past 30 years has produced some findings that can contribute to the development of selection procedures for automated systems. First, paper-and-pencil aptitude tests alone have been found insufficient to predict performance on the complex procedural tasks involved in ATC in its current environment. Second, the addition of a second-stage miniaturized training-testing program has improved the utility and validity of the ATCS selection process and reduced field attrition. This selection program, based upon nonradar separation, has been useful for predicting success in the radar environment.

As with selection research in other occupations, the research on air traffic control specialists suffers from lack of availability of criterion measures of ATC's job performance. Because the Screen measures task samples via the laboratory problems, the experience gained in developing measures of training performance for both the Screen and the Academy basic radar training courses could contribute to future efforts to develop criterion job performance measures for the automated ATC environment.

The current selection system has been found to have utility in decreasing the field attrition rate; however, it may not be the best selection system for radar ATCSs or the evolving automated occupation, and it is certainly very costly in terms of monetary and human resources. Therefore, the FAA is beginning to explore alternatives to the current methods. The goals are to have a shorter and less costly selection process, with predictive validity similar to the present system, in place within the next five years.

Clearly, the development of selection procedures for automated systems will be a difficult process, complicated by a lack of information about the job, varying expectations about eventual job task requirements, extensive time frames for validation, and a need to develop appropriate criterion measures of job performance. The time to start addressing these issue is now, so that development of selection procedures for the changing occupation can parallel the evolution of the job.

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APPENDIX A

Cognitive/Sensory Attribute Definitions from Computer Technology Associates' Job Task Analysis (4).

CODING — Transformation or translation of information for entry into the system; Converting textual information to graphics or symbols.

Example: Entering a PIREP (pilot report); Composing a flight plan amendment.

DECODING — Transformation or translation of information received.

Example: Recognizing a symbol for a handoff; Reading a Flight Data Entry.

DEDUCTIVE REASONING — Ability to reach a conclusion that follows logically from the known facts or data; Selection from among alternative answers or methods.

Example: Concluding that two aircraft are on intersecting paths.

FILTERING — Selection of inputs on which to focus attention in the presence of distracting stimuli or high workload; Selective attention; Overload accommodation.

Example: Identifying communication transmissions for attention during a period of heavy radio traffic.

IMAGE/ PATTERN RECOGNITION — Perception of spatial patterns and relations among static or dynamic visual inputs. May involve orienting oneself to the picture or configuration.

Example: Forming a picture of the traffic situation by reviewing Flight Data Entries on the Flight Data Display.

INDUCTIVE REASONING — Generation of an explanation for a set of specific data or instances, giving

structure and meaning to the information; Generalization of working hypotheses from specific events;

INDUCTIVE REASONING (cont.)
: Discerning basic differences and relationships among symbols, figures and figure patterns; Generating a new solution to a problem; Ability to make a knowledgeable assumption using incomplete data.

Example: Checking the adequacy of a proposed aircraft maneuver.

LONG-TERM MEMORY
: Mental storage of knowledge over a period of time and selective recall of items relevant to a situation.

Example: Remembering aircraft characteristics; Remembering procedural instructions or letters of agreement relevant to an uncommon situation, such as an airshow or large flight formation.

MATHEMATICAL/ PROBABILISTIC REASONING
: Translation of uncertainty into probability; Assigning a subjective probability regarding the likelihood of an event occurring; Ability to use probabilities to identify optimal courses of action.

Example: Assessing the risk of an aircraft maneuver.

MOVEMENT DETECTION
: Recognition of the physical movement of a visual object; Estimation of its direction or speed.

Example: Observing aircraft on the Situation Display responding to a clearance or advisory.

PRIORITIZING
: Ordering of events in sequence; Establishing priorities.

Example: Deferring a request for flight plan changes in the presence of more urgent activity.

SHORT-TERM MEMORY
: Mental storage and selective recall of of relevant information over a brief period of time.

Example: Briefly retaining and entering an aircraft call sign.

SPATIAL SCANNING — Rapid identification or detection of objects or events displayed in a wide or complicated visual field.

Example: Observing the Situation Display for new aircraft; Searching for data in a table.

VERBAL FILTERING — Same as FILTERING, but limited to voice communications.

VISUALIZATION — Observation of spatial patterns and subsequent mental transformations into other spatial patterns.

Example: Determining the effect of a proposed aircraft maneuver on other aircraft; Comparing intended time-position profiles for intersection in position/altitude/time.

APPENDIX B

Applicant OPM ATCS battery performance

Mean Scores on OPM ATCS battery component tests for
OPM open period from April-October 1985
N=8,826

Measure	Mean	Std. Dev.
Multiplex Controller Aptitude Test (MCAT)	73.0	16.6
Abstract Reasoning (ABSR)	31.5	9.3
Occupational Knowledge Test (OKT)	29.2	11.6
Transmuted Composite (TMC)	75.5	12.5
OPM Rating (RAT)	76.4	13.3

APPENDIX C

Academy Entrant OPM ATCS battery performance

Mean Scores on OPM ATCS battery component tests
for October 1985 through September 1986 Academy Entrants
N=402

Measure	Mean	Std. Dev.
Multiplex Controller Aptitude Test	94.3	5.8
Abstract Reasoning	40.6	5.5
Occupational Knowledge Test	36.5	14.6
Transmuted Composite	91.8	4.3
OPM Rating	93.7	4.0

APPENDIX D

Academy Performance Measures

Mean Scores for Academy Performance Measures
October 1985 through September 1986 Competitive Entrants
N=402

Block Test Ave.	95.7	4.4
Controller Course Test	93.4	5.4
Ave. 5 of 6 Laboratory Problems	74.0	7.1
Ave. Instructor Assessment	84.6	5.5
Ave. Technical Assessment	54.1	10.8
Controller Skills Test	82.0	7.5
Comprehensive Score	79.7	5.0

APPENDIX E

Correlations between Academy and OPM battery component scores
FY 1986 competitive entrants assigned to en route option
N=402

	OPM measures				
Measure	MCAT	ABSR	OKT	TMC	RAT
Academy measures					
Block Test Ave.	.02	.03	.14*	.02	.11
Controller Course Test	.01	.02	.25*	.02	.19*
Ave. 5 of 6 Lab. Problems	.22*	.04	.00	.20*	.15*
Ave. Instructor Assessment	.26*	.05	.03	.25*	.19*
Ave. Technical Assessment	.23*	.05	.01	.22*	.17*
Controller Skills Test	.16*	.12*	.03	.19*	.18*
Comprehensive Score	.24*	.08	.05	.23	.21*

*Correlations were significantly different from 0 at p<.01.

* U. S. GOVERNMENT PRINTING OFFICE: 1990--561-020/20440